1888–1902, made under the direction of Sir W. H. M. Christie; and eighteen charts of the Astrographic Chart of the Heavens, presented by the Royal Observatory, Greenwich; two lantern slides of spectroheliographs of the Sun taken at Kodaikánal Observatory, presented by the Director; six large transparencies from photographs of the Milky Way taken by Professor E. E. Barnard at Mount Wilson, California, presented by the Yerkes Observatory.

A Tentative Explanation of the Apparent Secular Acceleration of the Earth's Orbital Motion. By P. H. Cowell.

I have recently shown that, in order to satisfy the ancient eclipses of the Sun and Moon, it is necessary to assume that the mean longitude of the Moon contains a term $+11'' \, T^2$, and that the mean longitude of the Sun contains a term $+4'' \, T^2$.

These two arbitrary assumptions satisfied six solar eclipses. It was inconceivable that this could be a mere coincidence. Moreover, in the lunar eclipses of the Almagest, if we try to satisfy the records by assuming unknown secular accelerations for both Sun and Moon, we are led to precisely the same conclusions. I have felt it impossible to doubt that the records are trustworthy, and that no tables of the Sun and Moon will be completely satisfactory that fail to agree with those records.

There is still, however, some latitude of interpretation left. The eclipses determine at certain times the relative positions of the Sun, Moon, and node of the Moon's orbit. Two relations in fact exist between the four quantities, the position of the Sun, the position of the Moon, the position of the node, and the time.

The history of the subject is briefly as follows:

Halley discovered the secular acceleration of the Moon, Laplace showed that the changes produced by the planets in the eccentricity of the Earth's orbits would produce effects of the kind noted by Halley, Adams first correctly calculated the secular acceleration of the Moon's mean motion, and Professor Brown has given (*Monthly Notices*, lvii. p. 348) the following numerical values of the secular accelerations per century (measured from a fixed or uniformly moving departure point):

For the mean motion	$+5''.91$
For the node	$+6.56$

From the ancient eclipses I obtained as observed values of the secular terms:

For the distance from the Sun to the Moon ...	$+7''$
For the distance from the node to the Sun ...	-2.4

The excess of the observed over the theoretical secular accelerations is therefore :

From the Sun to the Moon	$+1''$
From the node to the Sun	$+4$
From the node to the Moon	$+5$

The mean motions of the Sun and Moon can only be obtained from observation, whereas the mean motion of the node can be obtained from theory ; as the theoretical motion of the node agrees with observation at the present time, it seems more reasonable to attribute the above excess of observed over theoretical secular accelerations to the Sun and Moon rather than to the node.

The observed excess to be explained is therefore :

For the Moon	$+5''$
For the Sun	$+4$

Since the time of Lagrange (who, by the way, refused to believe in the secular acceleration of the Moon as an observed fact until this idea had occurred to him) it has been considered permissible to assign any secular acceleration of the Moon to a lengthening of the day. If the day increases in length by one part in a million, the mean motion of the Moon would appear to increase by one part in a million ; so also would the Sun's mean motion ; but the numerical increase would only be one thirteenth part as large as for the Moon.

Mr. Eddington reminded me that Sir George Darwin has pointed out that the principle of conservation of angular momentum implies that, if the Earth is losing its axial rotation, the Moon's orbit must be at the same time expanding, and its angular motion diminishing.

Let N, n denote the angular velocities of the Earth's rotation and of the Moon's revolution, and let δN, δn denote the variations of these quantities in a century ; then the apparent secular acceleration of the Moon is

$$\tfrac{1}{2}\left(-\frac{\delta \mathrm{N}}{\mathrm{N}}+\frac{\delta n}{n}\right) \text{ times its mean motion}$$

and the apparent secular acceleration of the Sun is

$$\tfrac{1}{2}\left(-\frac{\delta \mathrm{N}}{\mathrm{N}}\right) \text{ times its mean motion}$$

where the factor $\frac{1}{2}$ is introduced, because secular accelerations are defined as the coefficients of T^2 in the corresponding quantity, instead of $\frac{1}{2}\mathrm{T}^2$.

δN, δn are both negative quantities, and it is easily shown that $\frac{\delta n}{n}$ is a very large fraction of $\frac{\delta N}{N}$, and hence that the ratio of the Moon's secular acceleration to its mean motion is a small fraction of the corresponding ratio for the Sun if tidal friction be the cause.

This is precisely the inference from ancient eclipses :

For the Sun the observed ratio is

$$4'' \text{ to } 100 \text{ revolutions, or } 3 : 10^8$$

For the Moon (excess over the Laplace effect)

$$5'' \text{ to } 1336 \text{ revolutions, or } 3 : 10^9$$

To fit in with these numbers it is necessary to show that

$$\frac{\delta n}{n} = \frac{9}{10} \frac{\delta N}{N}$$

so that

$$-\frac{\delta N}{N} + \frac{\delta n}{n} \text{ may be one tenth of } -\frac{\delta N}{N}$$

Let I be the amount of inertia of the Earth, m, a, e the mass, mean distance, and eccentricity of the Moon; then the moment of angular momentum is

$$I \,.\, N + mna^2(1-e^2)^{\frac{1}{2}}$$

The principle of the conservation of angular momentum will only give one relation between δN, δn and δe; but this relation is sufficient to show that $\frac{\delta n}{n}$ must be a large fraction of $\frac{\delta N}{N}$, though not necessarily nine tenths.

Differentiating and neglecting the effect of solar tides,

$$I\delta N + mna^2(1-e^2)^{\frac{1}{2}}\left[-\tfrac{1}{3}\frac{\delta n}{n} - \frac{e\delta e}{(1-e^2)}\right] = 0$$

or

$$-k\frac{\delta N}{N} + \tfrac{4}{3}\frac{\delta n}{n} + 4\,\frac{e\delta e}{1-e^2} = 0$$

where k is approximately unity, if we assume that the Earth's moment of inertia may be calculated as if it were homogeneous.

In this equation put $k = 1$, $\delta e = 0$

then
$$\frac{\delta n}{n} = \tfrac{3}{4}\frac{\delta N}{N}$$

which proves, at any rate, that $\frac{\delta n}{n}$ is a large fraction of $\frac{\delta N}{N}$. Also the ratio is increased if a positive value is assigned to δe.

In the same equation substitute the observed values

$$\frac{\delta N}{N} = -6 : 10^8 \qquad \frac{\delta N}{N} - \frac{\delta n}{n} = -6 : 10^9$$

(the factor 2 being introduced) then

$$\delta e = (\tfrac{6}{5} - k) \frac{2 \cdot 7}{10^7} = 0'' \cdot 01 \text{ per century if } k = 1$$

The supposition that the observed accelerations follow from the theory does not therefore conflict with the observed eccentricity.

On the other hand the transits of *Mercury* exhibit some slight evidence against this hypothesis, but perhaps not sufficiently important to destroy it.

Two conclusions follow from this paper:

I. It is absolutely wrong to assign an arbitrary secular acceleration to the Moon and none to the Sun, and to justify this course by the supposed action of the tides. This has been the practice of the *Nautical Almanac* since 1883.

II. On the hypothesis contained in this paper the rate at which the day is increasing is six parts in 10^8 or $0^s \cdot 005$ per century. This is about ten times as large as previous estimates.

Observations of the Magnitudes and Position of Nova Geminorum

By E. E. Barnard.

This star was discovered by Professor H. H. Turner on a photograph taken at Oxford on 1903 March 16.

My work on the Nova has consisted of comparisons of its light with that of certain stars and measurements of its position relative to small stars near it. I have also watched the star for any change of focus due to the usual changes in the spectrum of a Nova. The star was at first of a strong red colour, but this soon faded out and left it colourless. At first there did not seem to be any difference in the focus from that of an ordinary star, but in the latter part of April there seemed to be some slight difference, the star perhaps coming to a focus slightly outside of that for an ordinary star (see *Ap. J.* xvii. 1903, p. 376). The notes show that on 1903 August 31 the Nova was whitish and hazy. On 1903 September 21 at $15^h\ 45^m$, with a magnifying power of 700 diameters, the Nova was decidedly out of focus when compared with the other stars. Careful measures